



International Colloquium Transformer Research and Asset Management

Cavtat/Croatia, November 12 – 14, 2009

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INTERNATIONAL COLLOQUIUM

Transformer Research and Asset Management

PROGRAMME

Cavtat/Dubrovnik, Croatia, November 12 – 14, 2009
Hotel Croatia

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Welcome to the 1st International Colloquium “Transformer Research and Asset Management”



The 1st International Colloquium “Transformer Research and Asset Management” to be held in Cavtat from November 12–14, 2009 is organized by CIGRÉ National Committee of Croatia with CIGRÉ Study Committee A2 — Transformers, the Faculty of Electrical Engineering and Computing in Zagreb and the Centre of Excellence for Transformers in Zagreb.

On behalf of the Organizing Committee, we would like to thank the Institutions that have supported the Colloquium, namely: Končar Electrical Industries Inc and Siemens AG have kindly sponsored this Colloquium and Ministry of Economy, Labour and Entrepreneurship of Republic of Croatia as its patron.

Today it is quite clear that energy is a critical global issue, and transformers, which play a significant role in energy transmission and availability, have to be safe and reliable. Transformer industry is facing great expansion in some countries (China, India, Middle East, etc.), and at the same time we have the problem of ageing of transformers in the most developed countries, where power infrastructure was built in '60s and '70s of the last century. Thus, the topics that will be discussed at the Colloquium are as follows:

1. Numerical Modelling
2. Materials, Components and New Technologies
3. Transformer Life Management

Forty six contributions of 133 authors and co-authors from 20 countries are accepted for a two-day presentation. The papers published on CD of the Colloquium have been selected after careful peer reviewing, and give an interesting sampling of latest advancements and developments that are important in the transformer field. We are especially happy to be able to include four excellent invited papers by: O. Bíró, U. Baumgartner, K. Preis, G. Leber; D. Tschudi, P. Heinzig; A. J. Moses; G. Csépes, I. Kispál, B. Németh, Z. Laczkó, P. Výboštok.

This Colloquium gathers together transformer manufacturers and manufacturers of transformer components. Its objective is to provide a forum to facilitate the interactions between participants in a friendly academic atmosphere and to bring together international experts, identify best practices, and validate different technical solutions.

I would like to use this opportunity to invite you to scientific and competent technical discussions where the delegates will have an opportunity to network and develop their own contacts and introduce themselves to new trends and issues on modern power and instrument transformers.

We also wish to thank transformer manufacturers and manufacturers of transformer components who exhibit their achievements and products.

Finally, the organizers are also grateful to the Technical Committee who invested great effort to review the papers and prepare them for CD publishing.

Miroslav Poljak, Ph.D.
Chairman of the Organizing Committee

Željko Štih (Chairman, Croatia)
Zoran Anđelić (Switzerland)
Max Babuder (Slovenia)
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Zvonimir Valković (Croatia)
Slavomir Wiak (Poland)
Davor Zvizdić (Croatia)

3. ORGANIZING COMMITTEE

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4. PATRONAGE OF THE COLLOQUIUM



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6. PRESENTATIONS OF SPONSORS

Friday, November 13, 2009

2.00–2.30 p.m. Presentation of Silver Sponsor SIEMENS

7.00–7.45 p.m. Presentation of Golden Sponsor KONČAR

7. MAIN TOPICS

Numerical Modelling

- electromagnetic field
- coupled fields
- transients
- numerical modelling in design, etc.

Materials, Components and New Technologies

- insulating material
- magnetic material
- transformer components
- transformer new technologies, etc.

Transformer Life Management

- monitoring
- diagnostics
- failures
- asset management, etc.

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- 2. Z. Cheng, Q. Hu, N. Takahashi, B. Forghani**
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- 3. Ž. Janić, Z. Valković, I. Šulc**
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- 4. F. Zhalefar, M. Sanaye-Pasand**
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- 5. W. Calil**
DETERMINATION OF BUILDING FACTOR TO CALCULATE MAGNETIC LOSSES IN CORE OF POWER TRANSFORMERS BY FINITE ELEMENT METHOD
- 6. M. Ertl, H. Nicole, T. Villbusch**
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- 7. B. Cranganu-Cretu, M. Schneider**
COUPLED ELECTROMAGNETIC-THERMAL ANALYSIS FOR ABB POWER TRANSFORMERS
- 8. H. Campelo, C. M. Fonte, R.G. Sousa, J. C. B. Lopes, R. Lopes, J. Ramos, D. Couto, M. M. Dias**
DETAILED CFD ANALYSIS OF ODAF POWER TRANSFORMER

- 9. A. Sitzia, A. Baker, A. Davies, L. Clough**
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- 10. Z. Andjelic, X. Yang**
CONTROLLABLE REACTORS– FUNCTIONING AND ANALYSIS
- 11. B. Ćučić**
MAGNETIC FIELD IN THE VICINITY OF DISTRIBUTION TRANSFORMERS
- 12. E. Lesniewska, R. Rajchert**
APPLICATION OF THE FIELD–AND–CIRCUIT METHOD FOR COMPUTATION OF THE MEASUREMENT PROPERTIES OF CURRENT TRANSFORMERS WITH CORES CONSISTED OF DIFFERENT MAGNETIC MATERIALS
- 13. A. D. Theocharis, J. Miliias–Argitis, T. Zacharias**
THREE–PHASE TRANSFORMER MODEL FOR SLOW TRANSIENT AND POWER QUALITY STUDIES
- 14. F. Kelemen, L. Štrac, S. Berberović**
IMPACT OF GEOMAGNETICALLY INDUCED CURRENTS ON MAGNETIZING CURRENTS UNDER NO–LOAD CONDITIONS
- 15. T. Liu, M. Petit, T. Jung, H. Siguerdidjane**
SIMULATION WITH EMTP OF THE NO LOADED POWER TRANSFORMER'S RESIDUAL FLUX AFTER ITS DE–ENERGIZATION
- 16. M. Kaczmarek, D. Brodecki**
INFLUENCE OF THE CAPACITY BETWEEN WINDINGS OF THE VOLTAGE TRANSFORMER ON TRANSFER OF VOLTAGE SURGES
- 17. F. Zhalefar, M. Kalantari, J. Faiz**
STUDYING THE EFFECT OF LOCATION OF TAP–CHANGER SWITCH ON MAXIMUM FLUX DENSITY OF MAGNETIC CORE

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STATE OF THE ART OF SOLID INSULATION AFTER 125 YEARS OF TRANSFORMER PRACTICE
- 2. G. Acero, R.P. Marek**
LOW GAS GENERATION POWER TRANSFORMERS
- 3. B. Filipović–Grčić, D. Filipović–Grčić, S. Gazivoda:**
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- 4. M. Banović, A. Mikulecky**
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- 5. (Invited) A. J. Moses**
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- 6. M. Hastenrath, L. Lahn, R. Remaitre:**
NEW DEVELOPMENTS IN MANUFACTURING OF GO ELECTRICAL STEEL
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- 9. S. Muller, M. Petrovan Boiarciuc, G. Périgaud**
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- 11. R. Garotte, M. Hrkac, R. Szewczyk, R. Zannol**
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- 12. I. Šitar, M. Biloš, D. Valešić**
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- 13. Z. Godec, V. Cindrić, M. Banović**
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- 1. (Invited) G. Csépes, I. Kispál, B. Németh, Z. Laczkó, P. Výboštok**
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- 2. P. M. Monteiro, J.F. Martins**
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- 3. G. Daemisch**
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- 4. A. J. Kachler**
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- 5. M. P. Moreira, C.J. Dupont**
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- 6. L. A. Darian, V. P. Efremov, A. V. Kozlov, S .N. Luzganov, V. P. Polistchook, M. N. Povareshkin, A. V. Shurupov, N. E. Tsyba, A. N. Uchvatov**
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- 7. V. P. Efremov, A. V. Shurupov, V. P. Polistchook, V. E. Fortov, M F. Ivanov, A. D. Kiverin, E. M. Apfelbaum, V. S. Iorish, K. V. Khishchenko, L. A. Darian**
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- 8. A. de Pablo, V. Berezhny, D. Golovan, W. Ferguson**
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14. S. Keitoue, A. Keller, R. Gardijan

TRANSIENT OVERVOLTAGE ON-LINE MONITORING SYSTEM FOR POWER TRANSFORMERS

15. M. E. G. Alves, M. A. C. Mello

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I. NUMERICAL MODELLING

Chairmen: O. Bíró, Ž. Štih

Friday, 13 November, 9.15 a.m.

1. (Invited) O. Bíró, U. Baumgartner, K. Preis, G. Leber

NUMERICAL MODELING OF TRANSFORMER LOSSES

The paper presents a numerical method to predict the losses of electromagnetic origin in large power transformers. The approach is based on a three-dimensional model of the transformer including the tank, the iron core, various shieldings, clamping plates and the windings. The finite element method is used to compute the electromagnetic field described by potential functions taking account of the eddy currents occurring in different structural parts. Nonlinearity of all steel components as well as magnetic and electric anisotropy of all device elements made of laminated steel are incorporated into the model.

Once the electric and magnetic fields in the model have been numerically determined by the finite element method, the various losses are computed. The eddy current losses are directly obtained as Joule losses from the current density and the iron losses from the magnetic flux density using loss curves provided by steel manufacturers. Some results are presented along with comparisons with measurements.

2. Z. Cheng, Q. Hu, N. Takahashi, B. Forghani

STRAY-FIELD LOSS MODELING IN TRANSFORMERS

A series of well established power transformer-based benchmark models, referred to as Problem 21 Family approved by the International Compumag Society(ICS), are used for accurate modeling of stray-field loss problems in electromagnetic devices, especially in large power transformers, and validating different types of electromagnetic field solvers. In this paper, the configuration of the benchmark models, the industrial background of the member-models, the measured and calculated results for the models are outlined. The newly extended Problem 21 family makes it possible to study the saturation effect of magnetic steel, observe the electromagnetic behavior inside the laminated sheets and the solid plate, examine the variation of both iron loss and flux with the excitation patterns, and demonstrates the ability to solve practical engineering problems. All of these prove to be beneficial to the proper solution of the stray-field loss problems in large power transformers.

3. Ž. Janić, Z. Valković, I. Šulc

TANK LOSS FOR DIFFERENT LEADS ARRANGEMENT

High current leads in transformer can cause high stray losses and/or high temperature rises. This paper gives an overview of the advantages and disadvantages of different leads arrangement. All calculations are done for a 220 MVA transformer with finite element

method. Seven different arrangements are considered and compared – an arrangement with no leads, an arrangement with Y-connected leads and five different arrangements with Δ -connected leads.

4. F. Zhalefar, M. Sanaye-Pasand

CALCULATION OF NO-LOAD LOSS IN POWER TRANSFORMERS WITH FIVE-LIMB MAGNETIC CORE; A CASE STUDY

The main purpose of this paper is to calculate no-load loss in three-phase power transformers which use five-limb core in their structure. The most important difference between these types of transformers with conventional type ones which use three-limb cores is distribution of flux in the magnetic core. As would be observed, non-linear behavior of the magnetic core would be reflected in the flux distribution and therefore magnetic fluxes with distorted wave-shapes would be produced. This phenomenon could lead to some difficulties in calculation of no-load losses in various degrees of excitation.

In this paper a practical three-phase power transformer with a five-limb core has been chosen for simulation. For this purpose, the principle of duality method has been chosen for modeling of this 200 MVA, 400 kV transformer. This work is performed employing EMTP.

As would be shown, obtained results are in good agreement with the predefined value of no-load losses at various applied voltages which confirms capabilities of the used modeling method.

5. W. Calil

DETERMINATION OF BUILDING FACTOR TO CALCULATE MAGNETIC LOSSES IN CORE OF POWER TRANSFORMERS BY FINITE ELEMENT METHOD

This work presents a suggestion to calculate a correction factor of building factor in a core of power transformers, due to influence of losses in the magnetic junction. This factor allows correcting the value of no load loss in the core, obtained from manufacture curves, and their determination, up to now, it has been based, especially, in empirical and statistics estimates. The correction suggested to this factor is based in magnetic losses calculation which was obtained from computer simulation of the transformer by Finite Element Method FEM. Having this correction factor, could the accuracy of the calculation of no load loss, be improved, setting of the experimental value closer. Two types of magnetic joints, with and without step-lap, and three sizes of gap were studied; then, it was examined the influence of these parameters in the building factor. The simulations were run by commercial software which uses FEM in 2D.

6. M. Ertl, H. Nicole, T. Villbusch

STUDY OF ELECTROMAGNETIC FORCED WINDING VIBRATIONS AT POWER TRANSFORMERS BY COUPLED 3D MAGNETO-MECHANICAL ANALYSIS

Three-dimensional numerical models allow to investigate the fundamental physical processes related with winding vibrations and load noise generation of power transformers. This study gives an overview about the applied modelling principles and results of the asymmetric magnetic and mechanical field configuration. Thereby the magneto-mechanical coupling and fluid-structure-interaction is taken into account.

7. B. Cranganu–Cretu, M. Schneider

COUPLED ELECTROMAGNETIC–THERMAL ANALYSIS FOR ABB POWER TRANSFORMERS

The accurate analysis of the stray flux effects in power transformers is paramount for the correct design of the unit. We present in the following the ABB experience in evaluating the hot–spots on the tank walls of power transformers via coupled electromagnetic–thermal analysis, and the way the company managed to implement it as an industrial process. The specific needs of numeric analysis when performed on industrial devices are thus outlined. Examples are presented illustrating the above mentioned points. Furthermore – the design optimization based on the extensive usage of numerical analysis is presented as being identified by ABB as the natural way of further taking advantage of the simulation technology.

8. H. Campelo, C. M. Fonte, R.G. Sousa, J. C. B. Lopes, R. Lopes, J. Ramos, D. Couto, M. M. Dias

Detailed CFD analysis of ODAF Power Transformer

In spite of their high efficiency, Power Transformers must dissipate non disregarable amounts of energy due to the losses, which are mainly generated in the windings.. The heat generated in the coils is removed by circulating a fluid, typically mineral oil, between them. The geometrical configuration of the oil channels determines the oil flow distribution along the transformer, which affects the heat removal efficiency and the position and magnitude of the hot–spots. The control of the temperature of the copper isolation is essential to determine the life–time of the power transformers.

In the present case, directed oil forced air (ODAF) CORE type power transformer was simulated, where windings of different configurations are present with multiple oil channels in each. Due to the different possible paths for the oil, the variation of temperature and oil physical properties along the transformer, Computational Fluid Dynamics (CFD) is the most suitable tool to analyze the flow inside a power transformer, since experimental measurements are complex and intrusive and can only measure a limited number of discrete points.

9. A. Sitzia, A. Baker, A. Davies, L. Clough

SPECIALISED SOFTWARE TOOLS FOR TRANSFORMER ANALYSIS

This paper reports the development of specialized features for transformer analysis and design in AREVA T&D's commercial finite element (FE) package – SLIM Electromagnetic Engineering.

The features include the automated modelling of transformers for stray loss calculation and of winding insulation systems and bushings.

In the important area of improving solution accuracy, this paper reports the implementation and testing of a non–linear surface impedance formulation for the calculation of stray loss on magnetic steel components such as tanks and frames.

10. Z. Andjelic, X. Yang

CONTROLLABLE REACTORS– FUNCTIONING AND ANALYSIS

The paper presents the functioning and field-based analysis of the orthogonally flux type controllable reactor. The voltage regulation is recognized as a one of the key issues being faced in the area of long distance power transmission lines. Beside the voltage drop during peak loading periods, the phenomena of voltage increase at the end of the transmission lines during low load period (Ferranti effect) has to be taken into account when planning the design layout of the power system. Thus, the shunt reactors are important components in the EHV/UHV (Eltra/Ultra High Voltage) power systems used for the voltage regulation issues. One of their important roles is to compensate the reactive power. Typically for such compensation the *fixed* shunt reactors are used. Alternative concepts introduced recently are the *controllable* reactors. Among various controllable reactors schemes, the orthogonal flux type controllable reactor is remarked for its low harmonics and fast response time. The *controlling* effect of orthogonal flux type controllable reactor is achieved by controlling the saturation level of the parts of the magnetic core (saturable reactor). In this paper we present an efficient approach for the simulation of such controllable reactors using Integral Equation Method (IEM). The key information when analyzing this kind of devices are the controllable reluctances. The paper demonstrates usage of IEM for the computation of the inductances as a function of the DC current changes depending on the saturation levels of the magnetic material. The results are compared with the calculation results based on equivalent magnetic circuit calculation model.

11. B. Ćucić

MAGNETIC FIELD IN THE VICINITY OF DISTRIBUTION TRANSFORMERS

A quasi-static analysis of an oil-type distribution transformer was described to determine the ambient magnetic field in the surrounding region. Windings and terminals were assumed to be primary sources of the magnetic field. Core and tank of the transformer were modeled by secondary sources (surface current density, surface charge density and eddy current density). In order to find these sources, the system of integral equations was transformed into linear system. Magnetic field was calculated by evaluating volume and surface integrals. The calculated and measured results of the magnetic induction were compared on a 630 kVA transformer. Evaluation of the magnetic induction was made for distribution transformers in the range 50–2500 kVA.

12. E. Lesniewska, R. Rajchert

APPLICATION OF THE FIELD-AND-CIRCUIT METHOD FOR COMPUTATION OF THE MEASUREMENT PROPERTIES OF CURRENT TRANSFORMERS WITH CORES CONSISTED OF DIFFERENT MAGNETIC MATERIALS

The aim for this research was to estimate the influence of different proportions of joint two different magnetic materials in core construction on transformation errors of the current transformer. Analyses of the electromagnetic field distribution for different cases of current transformers were performed. Computations were carried out based on the finite element

numerical method and their results and tests of real-model were compared. In this paper, magnetic field distributions of current transformers and some diagrams of current error and phase displacement have been presented.

13. A. D. Theocharis, J. Milias-Argitis, T. Zacharias

THREE-PHASE TRANSFORMER MODEL FOR SLOW TRANSIENT AND POWER QUALITY STUDIES

In this paper, a three-phase transformer model is used for the calculation of slow transient response and power quality studies. The proposed model is based on previous published authoritative models for the eddy currents and the magnetic hysteresis. Specifically, Bertotti's work for the eddy currents is used and the hysteresis loop is introduced either by the mathematical model proposed by Tellinen or by the macroscopic model presented by Jiles-Atherton. Moreover, the magnetic core topology is completely taken into account. In addition, a systematic procedure is presented for the determination of the incremental self and mutual inductances of the windings. Simulations results are compared to published measurements in order to verify the proposed model. Furthermore, the simulation results show that the characteristic curve of the core material, the asymmetry of the magnetic core and the presence of nonlinear loads have a strong influence on the harmonic content of the currents in both sides of the transformer.

14. F. Kelemen, L. Štrac, S. Berberović

IMPACT OF GEOMAGNETICALLY INDUCED CURRENTS ON MAGNETIZING CURRENTS UNDER NO-LOAD CONDITIONS

Different approaches can be used to calculate the magnetizing current waveforms in no-load conditions with or without DC bias currents flowing through the windings. One is to utilize the finite element method (FEM) as described in [3]. However, this requires a great deal of computing power and, naturally, is highly time consuming. The other is solving a magnetic reluctance network. The primary objective of this paper is to compare the results of the solution to simple network of nonlinear magnetic reluctances combined with an optimization method, and the FEM analysis results on the simplified power transformer geometry. Optimization process is necessary to obtain the steady-state waveform to the magnetizing current in no-load conditions.

15. T. Liu, M. Petit, T. Jung, H. Siguerdidjane

SIMULATION WITH EMTP OF THE NO LOADED POWER TRANSFORMER'S RESIDUAL FLUX AFTER ITS DE-ENERGIZATION

The studies of no loaded power transformer's controlled switching strategies need a realistic simulation of residual flux. The objective of this paper is thus to propose a solution of the residual flux's simulation with EMTP-RV, using its current functionalities, when the single phase transformer is de-energized in steady-state regime without re-ignitions. The circuit breaker is placed between the source and the transformer.

In this paper, we first treat in details magnetic behavior of the transformer at the circuit

breaker's opening instant, as well as transformer's hysteresis loop modeling during current chopping, in particular the simulation of the residual flux. This model is then used for applications of multiple simulations using the energization strategy based on a preceding controlled de-energization. The results obtained are discussed and are quite satisfactory with regards to the expected ones.

16. M. Kaczmarek, D. Brodecki

INFLUENCE OF THE CAPACITY BETWEEN WINDINGS OF THE VOLTAGE TRANSFORMER ON TRANSFER OF VOLTAGE SURGES

Quantitative and qualitative analysis of the voltage surges transfer through the voltage transformers, due to microsecond pulse rise times, requires knowledge of capacitive parameters. Figure 2 shows a voltage transformer equivalent diagram for the higher frequencies with the elementary capacities consideration. On the basis of the diagram it is possible to estimate the equivalent capacities between the primary and secondary windings of the voltage transformer for a given configuration of the transformer clamps and the corresponding couplings between the primary and secondary sides. These capacitors are the path of the surges transfer between primary and secondary windings of the voltage transformer and may affect the value of the surges transfer factor. Values of the coupling capacities are derived primarily from the parameters of the voltage transformer insulation system, its dimensions and applied design solutions. In addition, the equivalent coupling capacities between the primary and the secondary sides of the voltage transformer are mainly dependent on the type of coupling eg C_m-dm or $Dm-dm$, through which the surges transfer takes place, and also depends on the secondary windings loads.

17. F. Zhalefar, M. Kalantari, J. Faiz

STUDYING THE EFFECT OF LOCATION OF TAP-CHANGER SWITCH ON MAXIMUM FLUX DENSITY OF MAGNETIC CORE

This paper discusses about two major strategies of tapping power transformers, namely CFVV and VFVV. In CFVV strategy which is more common, turns number of tapped winding changes so that smoothes the voltage across the un-tapped winding. In such strategy, peak value of flux density of magnetic core should not change considerably. However, in VFVV this variable would change.

For the case of power transformers which connected to EHV lines with huge short circuit level, CFVV will lead to placing tap-changer at LV side. However, this choice has special difficulties during design and manufacturing processes. In this paper it will be shown that it is possible for such power transformers to place tap-changer on HV side without facing major problem during operation of transformers.

Chairmen: D. Tschudi, I. Sitar

Friday, November 13, 3:00 p.m.

1. (Invited) D. Tschudi, P. Heinzig

STATE OF THE ART OF SOLID INSULATION AFTER 125 YEARS OF TRANSFORMER PRACTICE

The paper summarizes the state of the art criteria to design the insulation of liquid immersed transformers. Some of these principle design rules were established about 30 years ago and their roots may even be nearly 60 years old. However, they are still valid and used – of course adapted to the individual conditions – by a large number of transformer manufactures and sometimes even required in transformer specifications to provide uniform preconditions for all bidders.

Today, modern three dimensional field calculation tools enable a smart economic design of transformers fulfilling today's requirements regarding size and reliability. Even spatio-temporal distributions of the electric field in HVDC transformers can nowadays be calculated and evaluated in short time.

But for the successful use of today's available design criteria and evaluation tools the selection of materials and components, high quality manufacturing, appropriate processing, testing and long term experience are the indispensable basis.

2. G. Acero, R. P. Marek

LOW GAS GENERATION POWER TRANSFORMERS

The reliability of a transformer can be improved by reducing the ageing of its insulation system. At the same time, if repaired, an old transformer design can work to a higher level of power as long as the insulation can withstand exposure to the higher temperature levels developed under that loading condition. Some owners of transformers have even requested the repair of units with an increase in power capability.

Many proposals have been made in search of achieving better reliability of transformers as well as improving performance. Also, some standards have already considered the possibility of the use of these new technologies. Many of them are related to the use of high technology materials with better resistance to the temperature effects [1 & 2].

Two of these transformer types, called semi hybrid or hybrid are designed substituting part or the entire cellulose insulation with materials like polyamides, but the increase in cost makes this solution profitable only in cases where the restriction in space or reduced cooling of the units would certainly injure the cellulose materials. The oil filled high power transformers have been left on the side of this topic due to this cost, but now we can make proposals to improve large power transformer performance with a very low impact in the final price.

The result is either a transformer with such low cellulose degradation that it is reflected in the gas generation with levels well below the standards or a transformer which can be indefinitely overloaded, developing gases at levels currently considered normal.

3. B. Filipović–Grčić, D. Filipović–Grčić, S. Gazivoda

CALCULATION OF POLARIZATION PARAMETERS OF TRANSFORMER OIL–PAPER INSULATION FROM RECOVERY VOLTAGE MEASUREMENTS USING GENETIC ALGORITHM

The state of oil–paper insulation is the key factor for assuring a reliable operation of power transformers. The recovery voltage measurement (RVM) is one of the methods used to estimate the polarization spectrum. Analysis of the polarization spectrum is used to evaluate the condition of the insulation with respect to moisture content and aging.

In this paper, a new method based on genetic algorithm (GA) is used to determine elements that represent polarization process from RVM test results. Method was successfully tested on a simple circuit and then applied on power transformer.

4. M. Banović, A. Mikulecky

CONCEPT FOR RESEARCH OF COMBINED ELECTRIC FIELD AT LIGHTNING IMPULSE TEST FOR HV WINDINGS

The goal of this research is to qualify and to quantify the influence of radial stress on axial stress of transformer coil insulation at lightning impulse test. Combined electric field is investigated experimentally using complex models that simulate both radial and axial electric field. The models are made of flat wire and continuous transposed conductor (CTC), with different insulation increases and different spacer thickness. They will be vacuum dried and oil impregnated and will be tested in high voltage laboratory using lightning impulses in appropriate incremental steps. Because of statistical evaluation, 12 identical models of the same type (geometry) will be tested. Total number of model types including flat wire and CTC is 48. Partial discharges during lightning impulse testing will be checked too. Various potential design criteria, such as simple combined field stress, maximal electric field on the insulated conductor, safety factor along electric field line, stressed space and streamer criterion will be checked on the basis of the electric field calculated for the actual models geometry and obtained breakdown voltages. Paper describes all the basic steps in experimental investigation of combined stresses in transformer HV winding including models design and LI testing procedure.

5. (Invited) A. J. Moses

CHARACTERISATION AND PERFORMANCE OF ELECTRICAL STEEL FOR POWER TRANSFORMERS OPERATING UNDER EXTREMES OF MAGNETISATION CONDITIONS

The losses of grain oriented electrical steel, used in the vast majority of distribution and power transformer cores, are graded at 1.5/1.7 T, 50/60 Hz under sinusoidal flux conditions in the Epstein frame. The no–load core loss of such transformers is always greater than the nominal Epstein loss due to a number of reasons summarised in this paper. This is quantified as the Building Factor (BF), the ratio of the per unit (W/kg) no–load loss of an assembled core to that of the core steel graded by the Epstein test. There are increasing commercial pressures for more accurate prediction of the BF. This can be only achieved with a better understanding of its contributory parameters.

At any specified peak flux density (B_m), magnetisation losses increase with increase in deviation of the flux waveform from the ideal sinusoidal time variation. Such distorted flux is present even in the Epstein test. Other sources of uncertainty in Epstein testing including mean magnetic path length errors, mechanical stress, normal flux and corner effects are summarised.

In a growing number of applications, transformers are operated under extreme or non ideal conditions such as distorted input voltage, high core flux density or with dc off-set flux. Each may lead to increased core losses and cause difficulty in performance prediction or difficulty in assessing suitability of materials based on standard Epstein testing. In an assembled core, factors such as rotational flux, mechanical stress and flux non-uniformity due to core configuration contribute to the BF to different extents under sinusoidal or distorted magnetisation. It is shown that in many cases the results from Epstein testing should be more carefully evaluated in order to predict core BFs with acceptable accuracy.

The paper concludes with discussion of more appropriate loss prediction in laminations as a basis for better evaluation of transformer core losses to help material manufacturers in their development of new steel grades and to guide core designers in better use of existing steels in energy efficient cores.

6. M. Hastenrath, L. Lahn, R. Remaitre

NEW DEVELOPMENTS IN MANUFACTURING OF GO ELECTRICAL STEEL

Despite of a long history of continuously improved magnetic properties, the further development of grain oriented electrical steel is a challenging target with the aim of still lower losses for more energy-efficient transformers and less transformer noise, besides a further reduction of manufacturing costs by more compact and less expensive production routes. Lower loss materials can be achieved by further thickness reduction with retention of optimum texture and improved domain refinement. Reduction of manufacturing costs can be achieved with low slab reheating temperatures < 1300°C instead of up to 1400°C in the classical processes. A radical new method is thin slab casting and direct hot rolling used for steels with a system of inherent plus acquired inhibitors, the latter formed by nitriding the cold rolled strip. Another way for process shortening is to cast directly the hot strip from the steel melt by a twin-roll method.

7. Z. Zic, J. Rocks

SEISMIC PROOF HIGH VOLTAGE TRANSFORMER BUSHINGS

The high voltage equipment should ensure safe operation during and after different natural hazards, including earthquakes. High voltage oil to air transformer bushings have shown high vulnerability during past seismic events. There are two main reasons for this phenomenon: earthquake response spectrum and natural frequencies of high voltage bushings are in the same frequency range and second bushing's damping ratio is very low. These natural characteristics of high voltage bushing make it one of the most sensitive components in electrical power systems.

The paper focuses on 550 kV SeismicRIP® bushing modelling, numerical simulation and

its seismic qualification. An overview of main differences between the IEC 61463 – 2000 Technical Specification and two latest editions of IEEE 693 Recommendation is provided.

A three-dimensional FEM modelling approach was applied to perform a modal spectrum and dynamic analysis of the bushing. Bushing accelerations, as well as velocities and displacements under different ground-motion time history loads, have been calculated. The comprehensive experimental shake table testing was performed to validate the calculation results.

The Micafil SeismicRIP® transformer bushing passed the severe earthquake tests without any damage and was qualified to the high seismic level as per the IEEE 693 – 2005 Recommendation. It was demonstrated that the applied simulation methodology was able to predict bushing accelerations and displacements with reasonable accuracy.

8. D. Filipović–Grčić, M. Poljak, Ž. Štih

OPTIMISATION OF CONDENSER-TYPE BUSHINGS WITH OIL-PAPER INSULATION

Inside the paper-oil insulation of HV condenser-type bushings, conducting surfaces or capacitive shields have been in use for many years to control electric field distribution. Traditional design methods take into account dielectric stresses in axial and radial directions, but experience shows that partial discharges occur in the vicinity of capacitive shield edges and can severely affect the projected life of oil-paper insulation.

In this paper, a new criterion considering maximum stress at the shield's edge is introduced. Maximum permitted value of the stress at the shield's edge is obtained through numerous experimental tests and numerical field calculations based on the finite element method (FEM).

9. S. Muller, M. Petrovan Boiarciuc, G. Périgaud

PREVENTING OIL FILLED TRANSFORMER EXPLOSIONS WITH A FAST DEPRESSURISATION STRATEGY

Oil-filled transformer explosions are due to electrical arcs occurring in transformer tanks. Within milliseconds, arcs vaporize the surrounding oil and the generated gas is quickly pressurized. The pressure difference between the gas bubble and the surrounding liquid oil generates pressure waves, which propagate and interact with the tank. Then, the reflections of the pressure waves build up the static pressure, which rises and leads to the tank rupture since tanks are not designed to withstand such levels of static pressure. This results in dangerous explosions, expensive damages and possible environmental pollution. While protective walls surrounding transformers can contain the explosion and sprinklers can fight the induced fire, the current paper presents a strategy to prevent the transformer tank rupture. Once an electrical fault occurs, the fast depressurization of the tank is induced by quick oil evacuation to a reservoir in order to prevent the tank explosion. To evaluate the efficiency of this strategy, experiments and computer simulations are used. The experiments were performed on large scale transformers equipped with the protection. Besides, simulations of the consequences of an electrical arc occurring in a 200 MVA transformer geometry were run and the pressure maps obtained with and without protection were compared.

10. I. Rusu

ABSORBENT WATER BATTERY SET UP IN THE TANK OF OIL TRANSFORMER

The presence of water in paper of transformer coils leads to insulation deterioration and electric faults. In the tank of transformers, at ambient temperature, the water migrates from oil into the insulation paper. The water in paper is distributed uniformly.

At present times, for extracting the water from the insulation paper of coils conductors, with transformers in function, most used methods consist in heating oil at 60-70 Celsius degrees, and after, when the water migrates from paper in oil, treating the oil to extract the water online in special installation outside of transformers. But, heating the oil at 60-70 Celsius degrees means to heat also the conductor's insulation with the possibility to deteriorate the paper qualities.

One solution for this problem could be to set up an absorbent water battery into the tank of transformers. So, the water inside the transformer will migrate in paper insulation coils but also in the absorbent water battery. If the quantity of coils paper is equal with the quantity on paper of battery, only 1/2 of water will migrate into paper insulation coils.

11. R. Garotte, M. Hrkac, R. Szewczyk, R. Zannol

HYBRID TRANSFORMER FOR INNOVATIVE COMPACT SUBURBAN SUBSTATION

Effective operation of electrical power systems involves a wide range of different aspects. Besides technical matters like proper sizing and loading of the equipment, special attention shall be given to reliability, availability, total impact on the environment, etc... In addition, all requirements must be fulfilled while keeping the total owning cost as low as possible. To date, the growth of power demand is steadily eroding the existing power system spare capacity and, ultimately, its supply reliability. At the same time, building new power lines and substations or enlarging the existing ones is becoming more and more expensive.

To eliminate all those problematic aspects, a new concept for suburban substation was introduced by E.ON Distribución, putting challenging requirements on the transformer design. This paper describes how these specific requirements have been met by ABB, the transformer manufacturer.

12. I. Sitar, M. Biloš, D. Valešić

NEW DESIGN OF TRACTION TRANSFORMERS FOR FIXED SUBSTATIONS

In this paper an analysis of different designs of traction transformers is given. The paper describes three-limb transformer design for 7.5 MVA and 10 MVA units and two-limb transformer design for 15 MVA and 16 MVA units.

Paper also represents noise level measurement results and sound intensity frequency spectrum for 16 MVA unit. Based on results of measurements taken during heat run test on transformer loaded with continuous load equivalent to rated power, simulation of oil and winding temperatures is given for two most common overload cycles of traction transformers.

The paper also gives a description of design and technological measures necessary in case of need to prepare the transformer for short-circuit withstand test, including the procedure and results of tests successfully performed at KEMA High Power Laboratory.

13. Z. Godec, V. Cindrić, M. Banović

AUTOMATED TESTING OF POWER TRANSFORMERS

Digital measuring instruments make automation of measuring and testing possible. It is possible to integrate measuring instruments (equipped with communication interface) and personal computer (PC) through the software application in an automated measuring system. Automation is beneficial for frequent and complex time-consuming tests.

Benefits of automated testing include immediate multi-lingual test reports, increased accuracy and reliability of test results, complete measurement results (measurement uncertainty included), higher productivity of test engineers, higher test laboratory throughput, and reduced test costs.

The paper introduces automated measuring system and software application "ATT" (Automated Transformer Testing). The ATT has features of automated measurements (during routine tests, type tests and some special tests defined by IEC and IEEE standards), storage of data, and test report generation with complete measurement results.

14. D. Pavlić

AN INFORMATION MODEL FOR DETERMINATION OF INSTRUMENT TRANSFORMER COSTS

Market needs, such as shrinking instrument transformer life cycles, increased competition, rapidly changing technologies, and a variety in customers' demands represent global companies driving forces in the instrument transformers production. Delivery time for instrument transformer as a tailor made product has been reduced up to six months from the contract agreement. Therefore, it is important to accurately estimate the instrument transformer costs in the offering phase. Automatic estimation of instrument transformer costs calls for information exchange between several IT systems in the companies: PDM, ERP and PM. These IT systems need to be fully integrated for automatic estimation of instrument transformer costs because each system separately covers only one part of the information needed for automatic estimation of instrument transformer costs. An information model for estimation of product cost consists of product and process domains which are mapped together. To achieve mapping between these domains, the mapping parameters are defined. These parameters are: *Activity_id*, *Resource_id* and *Quantity*. Automatic estimation of costs based on accurate information from different IT systems results in fewer deviations between estimate cost and real cost.

Chairmen: C. Sumereder, A. Mikulecky
Saturday, November 14, 9:00 a.m.

1. (Invited) G. Csépes, I. Kispál, B. Németh, Z. Laczkó, P. Výboštok

HUNGARIAN EXPERIENCES REGARDING ON SITE REFURBISHMENT OF POWER TRANSFORMER ESPECIALLY BY APPLICATION OF PD LOCATION WITH COMBINED ELECTRICAL AND ACOUSTICAL MEASUREMENTS

This paper presents a short view of on-site routine processes, high voltage electric test and onsite repairs of large transformers in the Hungarian National Grid with special regard to the on-site disassembling with a lifting technology and the on-site induced HV test with application of PD location with combined electrical and acoustical measurements. This paper describes a special case study of a 30 years old, 160 MVA, 220/120 kV transformer. The case study of this paper illustrates the difficulty and the experiences of Hungarian life management of transformers. The case study demonstrates the effectiveness and feasibility of the on-site refurbishment, the induced HV test and the PD location with combined electrical and acoustical measurement.

2. P. M. Monteiro, J.F. Martins

TECHNIQUES FOR POWER TRANSFORMER LIFE CYCLE EXTENSION

The following paper intends to present on a first stage a resume of the applied strategy and techniques for power transformer maintenance, referring selection criteria of the transformer for refurbishment and presenting follow-up results of the applied techniques in the last 8 years.

On a second stage, the article presents a practical application of this maintenance strategy, through the report of a successful refurbishment on two 126 MVA 150/60 kV transformers with severe degradation and hotspots on the main tank due to problems in the magnetic core, including selection criteria, local and network planning restrictions, diagnosis to estimate remaining life expectancy to validate refurbishment and repair costs, description of the main operations and final results.

3. G. Daemisch

THE TRANSFORMER USER – TRAPPED BETWEEN RAPIDLY DWINDLING LIFETIME STRENGTH OF OLD TRANSFORMERS AND DISCUTABLE BEHAVIOR OF NEW TRANSFORMERS

The fact, that due to deregulation, privatization and other changes in the energy industry were changed the maintenance strategies from the classical time based systems mostly to event based ones. For transformers this cannot be an adequate strategy. On the other hand the production capacity of the transformer industry was drastically reduced in the last 20 years. In the following the author reports a condition based proven strategy. The most important point is to cope with the non linear life time behavior of transformers. There are

on the other hand also proven preservation possibilities, nevertheless without an on time planning all these strategies must fail, since only already existing life time strength can be preserved. A fine tuned exploitation of the assets life time strength is a highly economic foregoing, the repayment of such investments is normally in a less than one years frame!.

4. A. J. Kachler

Transformer Life Management (TLM), Reliability. The main Aspects for Manufacturers and Users

The author proposes a unique Definition of In-Service Reliability on the basis of ANSI Standard C57.117 (1986).

Reliability is not yet defined uniquely and therefore the resulting resolutions and measures differ greatly worldwide. This leads to different measures [1] – [16]. Comprehensive efforts have been directed to evaluate Remaining Life, Ageing Processes and Diagnostics. It has shown, that these efforts must be continued, in order to improve transformer engineering and diagnostics. We need experience in Transformer behavior (diagnostics) and evaluation of symptoms of incipient defect/failure conditions. Besides of the proposal of a unique definition of reliability, this paper elaborates on the Main Aspects of Reliability: for Part 1: Responsibilities for Manufacturers; for Part 2: Responsibilities for Users

We discuss the necessity for continued efforts in Transformer Research to the benefit of both manufacturers and users.

The conclusions summarize the essential responsibilities of both manufacturers and users to improve Reliability to the benefit of TLM and Asset Management.

5. M. P. Moreira, C.J. Dupont

IDENTIFICATION AND PRIORIZATION OF FAILURE MODES IN POWER TRANSFORMERS USING RCM PROCESS AND THE PROMETHEE METHODOLOGY

This report explores the use of RCM (Reliability Centered Maintenance) and the multicriteria PROMETHEE methodology as tools in power transformer diagnostic systems. The objective of the proposed model is to help the user in finding the best ranking in a set of failure modes (alternatives) given for a set of previously identified abnormalities (defects). A real example in a 387 MVA transformer open for inspection after overheating evidences is used to show the adequacy of the proposed modeling.

6. L. A. Darian, V. P. Efremov, A. V. Kozlov, S. N. Luzganov, V. P. Polistchok, M. N. Povareskin, A. V. Shurupov, N. E. Tsyba, A. N. Uchvatov

THE GAS FORMATION IN THE TRANSFORMER OIL UNDER ACTION OF ELECTRICAL ARC AND PARTIAL DISCHARGES

The experimental study of the gas formation in electrical arc and partial discharges in transformer oil is presented. The arc energy was 10–100 kJ, the duration of arc discharge was 1–5 ms. Measured value of the resistance to gas formation in arc discharge was about

110 I/MJ. The obtained results may be used to testify the shell of oil-filled transformers to the action of high pressure, which arises due to internal short-circuit. The partial discharges were investigated in the range energies from 0.6 to 600 J. The resistance to gas formation in partial discharges was depended on the experimental conditions and was about 0.85 –120 I/MJ.

**7. V. P. Efremov, A. V. Shurupov, V. P. Polistchook, V. E. Fortov,
M. F. Ivanov, A. D. Kiverin, E. M. Apfelbaum, V. S. Iorish,
K. V. Khishchenko, L. A. Darian**

PHYSICAL INVESTIGATION AND EXPLOSIONS SIMULATION OF OIL-FILLED TRANSFORMERS

The physical foundations of the new method of determining the explosion-proof character of the oil-filled transformers are examined. This method is based on the replacement of the pulse of the high pressure, which appears with the internal short circuit, on the pulse arising with the explosion of chemical substances. The necessary conditions, when the action on the shell of the transformer of the explosion of chemical substances is equivalent to the action of pulse electric arc, are discussed.

8. A. de Pablo, V. Berezhny, D. Golovan, W. Ferguson

CONDITION ASSESSMENT OF TRANSFORMER TAP CHANGERS BY OIL ANALYSIS

This paper describes an in service condition assessment study of three transformers at a power plant and in particular the results concerning the OLTCs installed on the three 400 kV, GSU transformers. One 435 MVA unit and two smaller GSU transformers each 305 MVA. We revealed an OLTC defect in the 435 MVA unit (1X)).

The study was carried out by means of dissolved gas analysis (DGA) and particle content of the oil of the three diverter switch compartments of the transformer.

Oil analysis results indicated a presumed failure condition in the diverter switch of phase 1X, associated with abnormally high energy dissipation, which leads to the accelerated oil ageing and decomposition with formation of great amounts of carbon particles. Abnormal heating may be caused by contamination of contacts surface, with oil ageing and oxidation by-products, formation of cavities and dents on contacts working surfaces, decrease of pressing force of movable contacts and increase of transient resistance of fixed contacts.

9. W. Sorgatz

EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT THE GAS-IN-OIL ANALYSIS ACCORDING ASTM 3612 / IEC 567 / IEC 61181 HEAT RUN TEST

In the past, maintaining operational equipment has become more and more important.

The objective is to achieve an optimal usage and extended service life of transformers and to reduce the number of unexpected failures. Apart from detecting faults at an early stage, saving costs is an essential aspect as regards the maintenance of transformers. High availability means an increase in your efficiency and thus also in your profitability. The well

known method to calculate the condition of the transformer is the DGA Analysis. To get accurate and reproducible results ENERGY Support developed a new Mobile System to get the same results in the field as in the laboratory.

10. R. Eberhardt, M. Muhr, C. Sumereder

DETERMINATION OF HUMIDITY IN OIL IMPREGNATED CELLULOSE INSULATION SYSTEMS

The lifetime of oil impregnated insulation systems is strongly dependant to the mechanical strength of the cellulose molecules. Water accelerates the degradation of the paper insulation. For this reason the humidity in oil and oil impregnated cellulose insulation systems of power transformers is an essential factor for accelerated aging. Therefore the determination of the water content in the liquid and solid insulation is of high interest for lifetime assessment. In this paper the focus is laid on the different methods for the determination of humidity. Chemical as well as physical and dielectric methods were compared and the results of laboratory tests and tests at distribution transformers were discussed.

11. A. Mikulecky

HOW TO PREVENT TRANSFORMER BUSHING FAILURES?

About a quarter of all transformer failures are caused by bushings and they are the most common reason of transformer fire with collateral and ecological damages. That situation can be prevented by applying off-line and on-line bushing monitoring, especially by measuring of capacitance C and dielectric dissipation factor $\tan\delta$. The investigation of temperature dependence of C and $\tan\delta$ were implemented on specially designed models with different moisture contents in the insulation and during artificial ageing. New criteria for diagnostics of OIP bushing insulation system condition, applicable to off-line and on-line monitoring, based on investigation results and a broad experience with bushings diagnostics, are proposed.

12. S. M. Hoek, K. Rethmeier, R. Plath

NOISE SUPPRESSION BY MULTI-CHANNEL PD MEASUREMENTS AND REAL-TIME DATA EVALUATION

Partial discharge measurements on transformers are an accepted tool of quality control, in factory and on site. Common methods to improve the quality of noisy PD data are filtering and gating. Recently a new method was introduced, which is able to clearly separate different

PD sources within the transformer as well as separate PD from noise. This multi-channel synchronous measuring method compares amplitude relations of simultaneous PD sources of three phases (3PARD). PD pulses propagate from their origin to the decoupling site, while even cross-coupling to the other phases. PDs from different locations inside the insulation will lead to unique pulse triples at the 3 decoupling positions. The amplitude relations of the 3 synchronously decoupled pulses of one pulse source will be nearly constant. A

comparison of these amplitude relations allows a classification of different noise sources and single PD failures within the DUT by.

As a new approach of PD source separation the 3PARD method was adapted to the 3–Center–Frequency–Relation–Diagram 3CFRD. This technique allows PD and noise separation by comparing the frequency spectrum of different PD mechanisms and noise pulses. In real time a diagram can be constructed with similar clusters as the familiar 3PARD. As 3CFRD is not inevitably linked to 3–phase systems like power transformers it can also be applied to single phase transformers, VTs and CTs. This paper will present promising results from the latest multi–channel PD measurements.

13. M. E. G. Alves, R. Albuquerque

ON–LINE MONITORING OF 345–138/13.8kV 150MVA AUTO–TRANSFORMER BANK WITH ON LOAD TAP CHANGES

In order to increase the substation's transformation capacity, Furnas substation in the city of Campinas, received a new bank of 345–138/13,8kV 150MVA single phase, auto–transformers with on load shunt changers, comprised of two phases manufactured by Jeumont/Vatech (France) in 2001 and one phase ASEA, year 1975.

Moving with the general trend of migration from preventive to predictive maintenance, the Jeumont transformers were specified by Furnas, using a contract amendment, for delivery already equipped with sensors and on–line monitoring system. This scope also included the modernization of the ASEA phase by installing sensors for monitoring and substitution of electro–mechanical devices by Intelligent Electronic Devices (IEDs).

The outcomes achieved by operating with this online monitoring system on the field will be shown, including the occurrence of a defect in one of the phases of the bank during the period when the system was being installed, with a part of the data capture system already in operation.

We will also show how the readings obtained in the implementation phase helped in investigating the causes for the occurrence.

14. S. Keitoue, A. Keller, R. Gardijan

TRANSIENT OVERVOLTAGE ON–LINE MONITORING SYSTEM FOR POWER TRANSFORMERS

Since there is an increasing interest in the development of new monitoring techniques for better asset management, a team of specialist from Končar – Electrical Engineering Institute redesigned the existing transformer monitoring system Končar TMS and upgraded it with a feature of a transient voltage recorder, which is presented in this paper.

The impact of overvoltages on a transformer is analyzed, and their classification according to IEC standard is given. As the basis for selection of appropriate platform for the new system, an analysis of hardware requirements for measuring and data acquisition equipment is done. The system architecture of the chosen solution is presented with a short description of key hardware and software components.

After completion of the design, the system was installed on several 400 kV and 220

kV transformers and one 110 kV shunt-reactor. Further development of the system is discussed with an overview of the experience gained so far.

15. M.E.G. Alves, M.A.C. Mello

EXPERIENCE WITH ON-LINE MONITORING OF CAPACITANCE AND TANGENT DELTA OF CONDENSIVE BUSHINGS

Capacitance and tangent delta are acknowledged as some of the main parameters for bushing insulation condition diagnosis, because they are directly affected by the deterioration of the insulation. This article intends to display a technique used in on-line monitoring of capacitance and tangent delta of bushings, in addition to an actual field deployment experience in monitoring 550kV and 245kV bushings on auto-transformers and power reactors.

Results shown were obtained during the course of approximately one year, including on-line detection of insulation deterioration for a 550kV bushing, avoiding a possible failure with explosion, later proven by off-line measurements of capacitance and tangent delta and by gas-chromatography analysis of oil sample from the bushing.

Additionally, some practical consideration about practical issues related to installing online bushing monitoring systems on transformers equipped with Bushing Potential Devices (Dispositivos de Potencial de Bucha – DPB), where the tap of the bushing is already occupied, as well as on equipment on which it was possible to make the connection directly to the tap of the bushing.

9. TIME-TABLE

Bobara Hall / 1st floor / Hotel Croatia

Thursday, November 12, 2009

2.00 a.m. – 8.00 a.m.	Arrival and Registration
8.00 a.m.	Welcome Cocktail and Dinner

Friday, November 13, 2009

8.30 a.m. – 9.00 a.m.	Opening Session
9.15 a.m. – 10.45 a.m.	Numerical Modelling
10.45 a.m. – 11.00 a.m.	Break
11.00 a.m. – 12.15 a.m.	Numerical Modelling
12.30 a.m. – 1.30 p.m.	Lunch
2.00 p.m. – 2.30 p.m.	Presentation of Silver Sponsor
3.00 p.m. – 4.30 p.m.	Materials, Components & New Technologies
4.30 p.m. – 5.00 p.m.	Break
5.00 p.m. – 6.30 p.m.	Materials, Components & New Technologies
7.00 p.m. – 7.45 p.m.	Presentation of Golden Sponsor
8.00 p.m.	Golden Sponsor's Dinner

Saturday, November 14, 2009

9.00 a.m. – 10.30 a.m.	Transformer Life Management
10.30 a.m. – 11.00 a.m.	Break
11.00 a.m. – 12.30 a.m.	Transformer Life Management
1.00 p.m. – 2.00 p.m.	Lunch
2.30 p.m.	Tour of Dubrovnik
7.00 p.m. – 10.00 p.m.	Dinner in Dubrovnik or its neighbourhood
10.00 p.m.	Return to the hotel

Sunday, November 15, 2009

6.00 a.m. – 12.00 a.m.	Departure
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10. REGISTRATION AND INFORMATION OFFICE

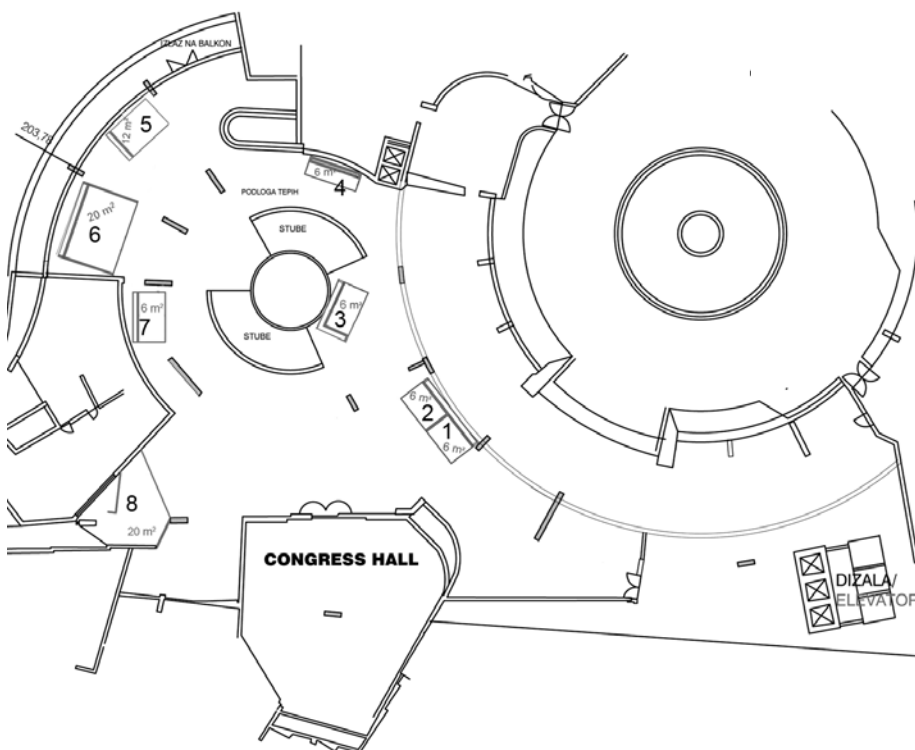
All participants should register immediately after arrival at the Registration and Information Office (in the lounge of the Hotel *Croatia*) where they will receive all conference materials and information regarding the Colloquium.

Transformer Research and Asset Management

Cavtat/Dubrovnik, Croatia, November 12 – 14, 2009, Hotel Croatia



EXHIBITING STANDS HOTEL CROATIA CAVTAT 1ST FLOOR



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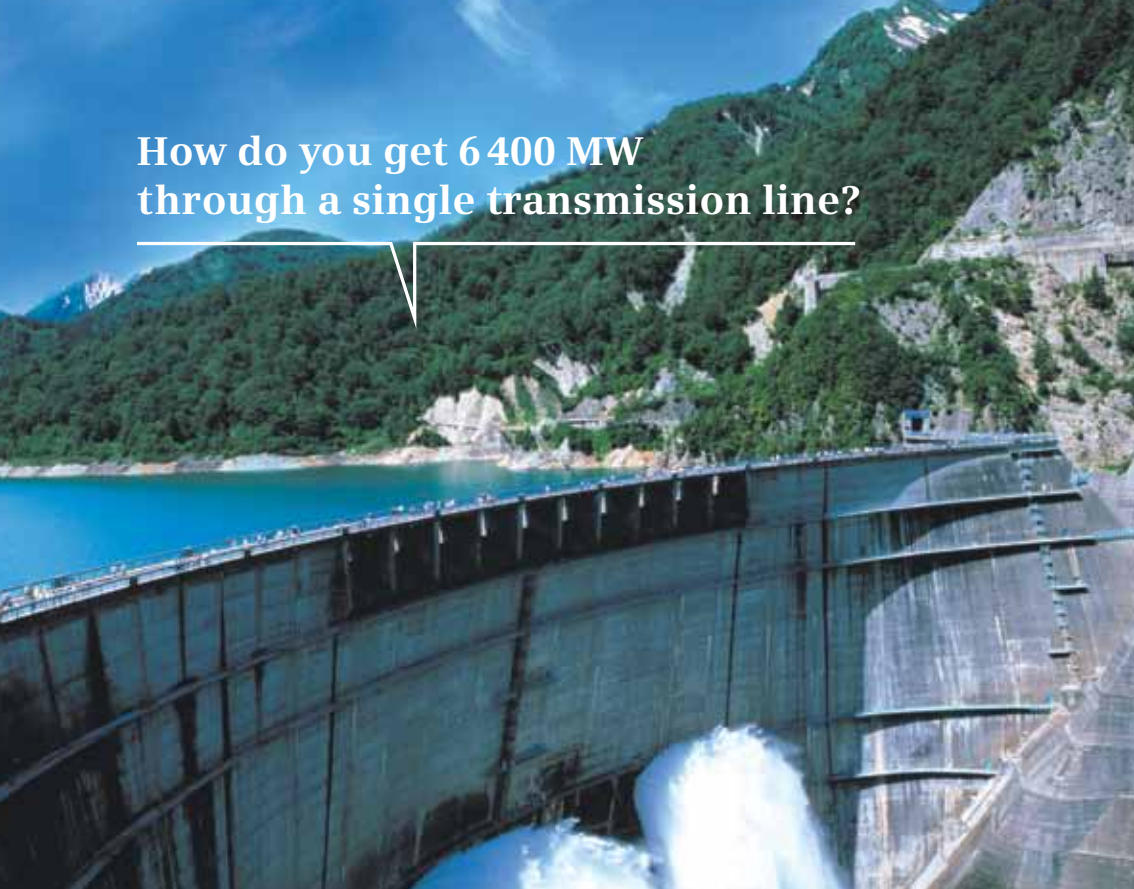
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Generating power in a sustainable and ecologically responsible way is one thing, but the energy needs to be transported to the centers of consumption in an efficient and likewise environmentally sound manner. This is where Siemens' 800 kV ultra high voltage transformers come into play. Specially designed to pave the way for large-scale bulk transmission at outstandingly little loss, this new generation of converter transformers will feed the longest and highest capacity HVDC transmission link in the world in the near future: the new 800 kV/6 400 MW UHVDC transmission link from Xiangjiaba hydropower station in southwestern China to Shanghai in the east.

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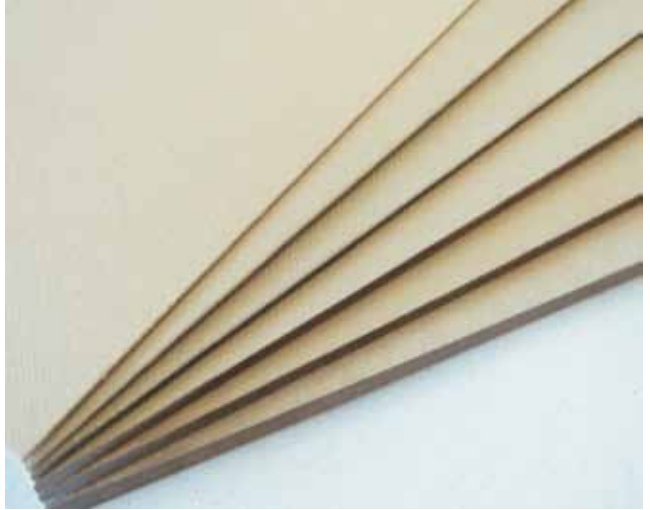
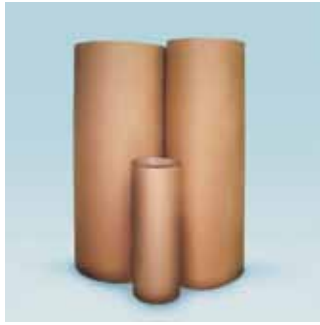
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Transformerboard Factory

ENPAY

ENBOARD- ENPAY TRANSFORMERBOARD WE'VE ALWAYS BEEN AHEAD OF THE CURVE.

ENPAY is a globally-leading producer in Transformer Components. We provide the most forward-thinking, cutting-edge solutions to our customers World wide. Our best practices deliver unsurpassed economical performance for our clients in the energy sector.

We are proud to announce that ENPAY started Transformerboard production with a production capacity of 10,000 tons a year. ENPAY production range for Transformerboards are thicknesses between 1 mm and 8 mm with dimensions up to 3,200 mm by 6,300 mm according to IEC 60641 standards.



My Dad is a Testing Engineer

...and OMICRON's transformer testing solutions make his job really easy!

Go ask my father, because he knows how to detect winding defects and core faults in power transformers easily and fast. With OMICRON's multifunctional primary test sets he can carry out a reliable condition assessment of insulations by

measuring the dissipation factor ($\tan \delta$), the moisture content, or by detection and analysis of partial discharges.

With this compact equipment also resistances, impedances, inductivities and capacitances can

be measured, or the condition of a tap changer can be assessed.

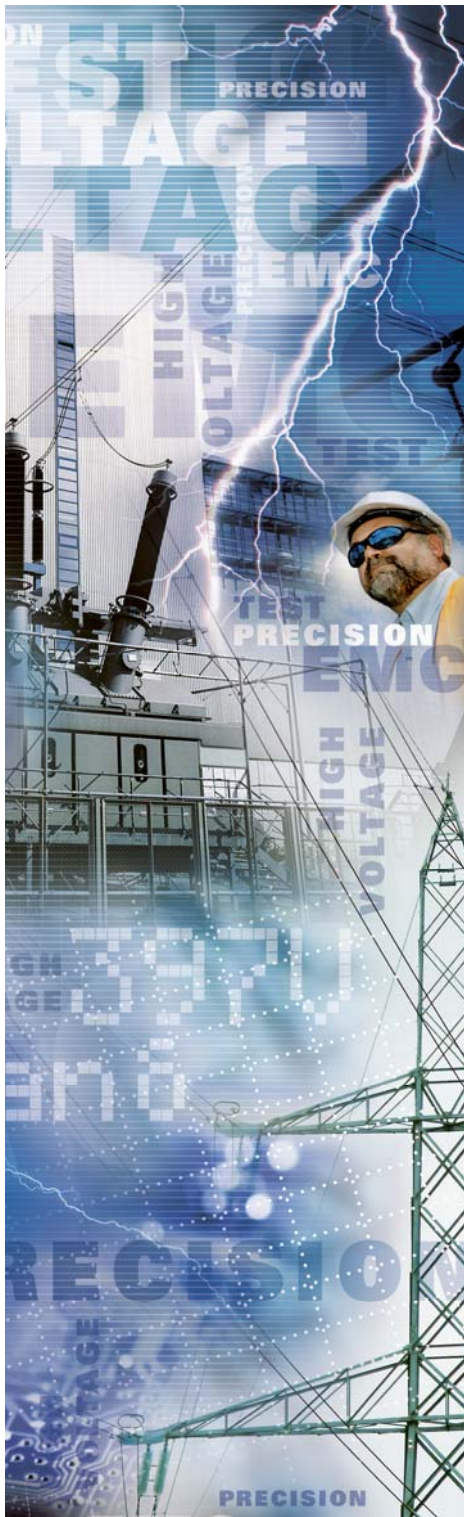
All in all my dad is really convinced that genuine innovation from OMICRON just made his work simpler than ever – take a look!

Visit us at
our booth no. 5



OMICRON





HAEFELY 
HIGH VOLTAGE TEST

Tettex 
INSTRUMENTS

**Precision. Swiss Made.
Since 1904.**

Haefely is market leader in the field of high voltage test equipment for the transformer industry. We offer a wide range of instruments and complete high-voltage test installations for measurements and diagnostics in laboratories, factories and in the field.

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